MECHANICS OF RUNNING SKYLINES

by
Charles N. Mann

PACIFIC NORTHWEST Forest and Range Experiment Station
U.S. Department of Agriculture · Forest Service
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CONTENTS

1.0 INTRODUCTION

In April 1967, the running skyline system was presented.[1] Since then, several running skyline units have been developed for yarding partial and clear cuts. Their success indicates that they may achieve increasing acceptance by all concerned with efficient logging and improved forest practices. Because of the importance of running skylines, it is timely to present a description of the various systems and procedures for determining their payload capability. These procedures are presented in the form of worksheets to simplify solutions. They are intended primarily as a practical tool for those who plan running skyline operations. The mathematical derivation of the procedures is included for those interested in a full understanding of the mechanics of running skylines.

[1] Lysons, Hilton H., and Mann, Charles N. Single-span running skylines. Pacific Northwest Forest & Range Exp. Sta. U.S.D.A. Forest Serv. Res. Note PNW-52, 7 pp., illus. 1967.

A standing skyline employs a fixed or standing line for support of the load and additional lines for movement and control. The running skyline system eliminates the need for a standing line. Figure 1(1) shows the essential elements of the running skyline. As the name "running skyline" implies, the traveling lines provide lift and movement to the suspended load. The main and haulback drums are interlocked in a manner that maintains relatively constant tensions at any position of the lines. Since two lines support the load, they can be smaller than a single line for the same load.

A feature of the running skyline system is that it adjusts itself to the weight of the load; i.e., the deflection increases with heavier loads to provide lift to the suspended load without adding to the line tensions.

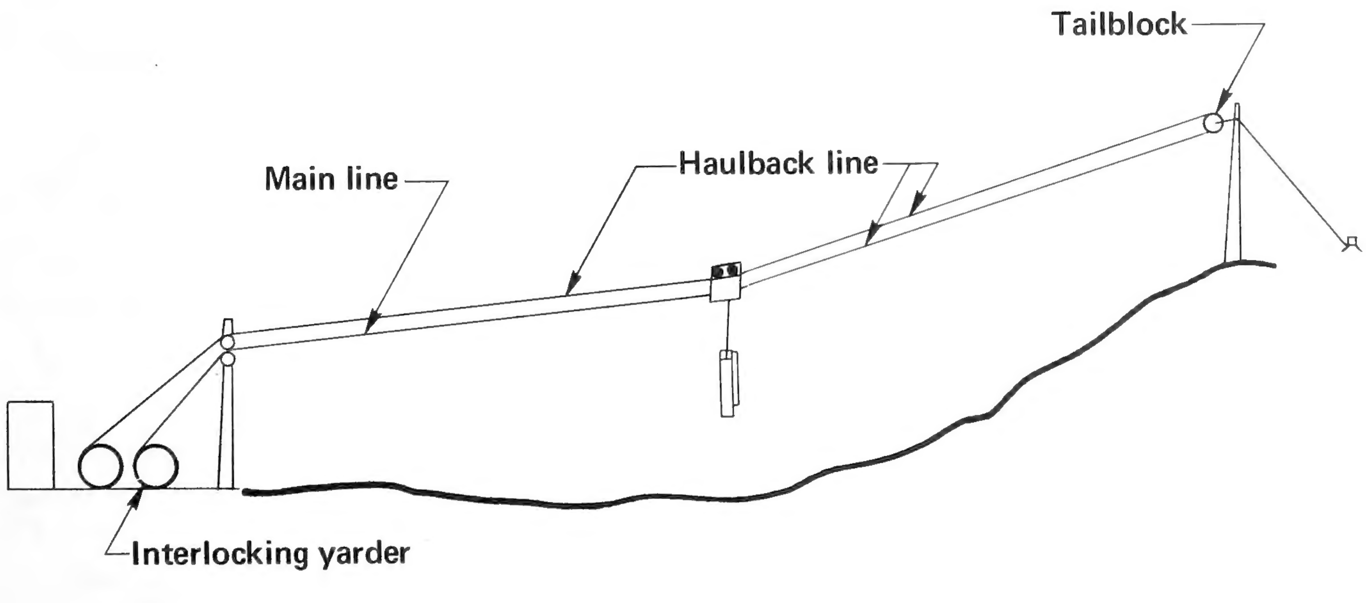


Figure 1(1).--Running skyline system.

2.0 SYSTEMS IN USE

Running skylines have been used in the Pacific Northwest with grapples and skyline-crane carriages. Yarding distance capability presently approximates high-lead equipment, but indications are that larger cable drums will be made available to greatly extend this distance. The grapple system, which is limited to clearcut operations, requires a two-man crew as compared to five or six men on a typical high-lead operation. High mobility is one of the principal design features of running skyline systems.

A typical running skyline-crane carriage is shown in figure 2(1). The third line shown is used to pull slack in the main line as needed to reach the load. Carriages of this type have been used both as skyline cranes and with grapples. When used with a grapple, the slack-pulling line, which reeves through the carriage, functions as the grapple-opening line, as shown in figure 2(2). Grapples requiring only main and haulback lines for operation have also been used with the running skyline. One grapple of this type cycles to open and close. Another uses electronics and an independent power source for operation.

In the running skyline analysis which follows, the system payload capability is based on the safe working load of the lines when the load is suspended directly below the carriage. However, it is important to be aware of other situations which can impose high stresses on the lines. If the log is on the ground between the carriage and the tailblock when the lines are tensioned, as shown in figure 2(3), tension in the main line is increased until enough force is applied to move the log. For this condition, tension in the haulback line is less than in the main line. A more serious situation is encountered when the lines are tensioned with the log on the ground between the yarder and the carriage, as shown in figure 2(4). Again, the main line tension is increased until enough force is applied to move the log. However, in this case the main line imposes a block purchase on the haulback line. In an extreme condition, tension in the haulback line can approach twice that in the main line. Therefore, this yarding situation should be avoided whenever possible.

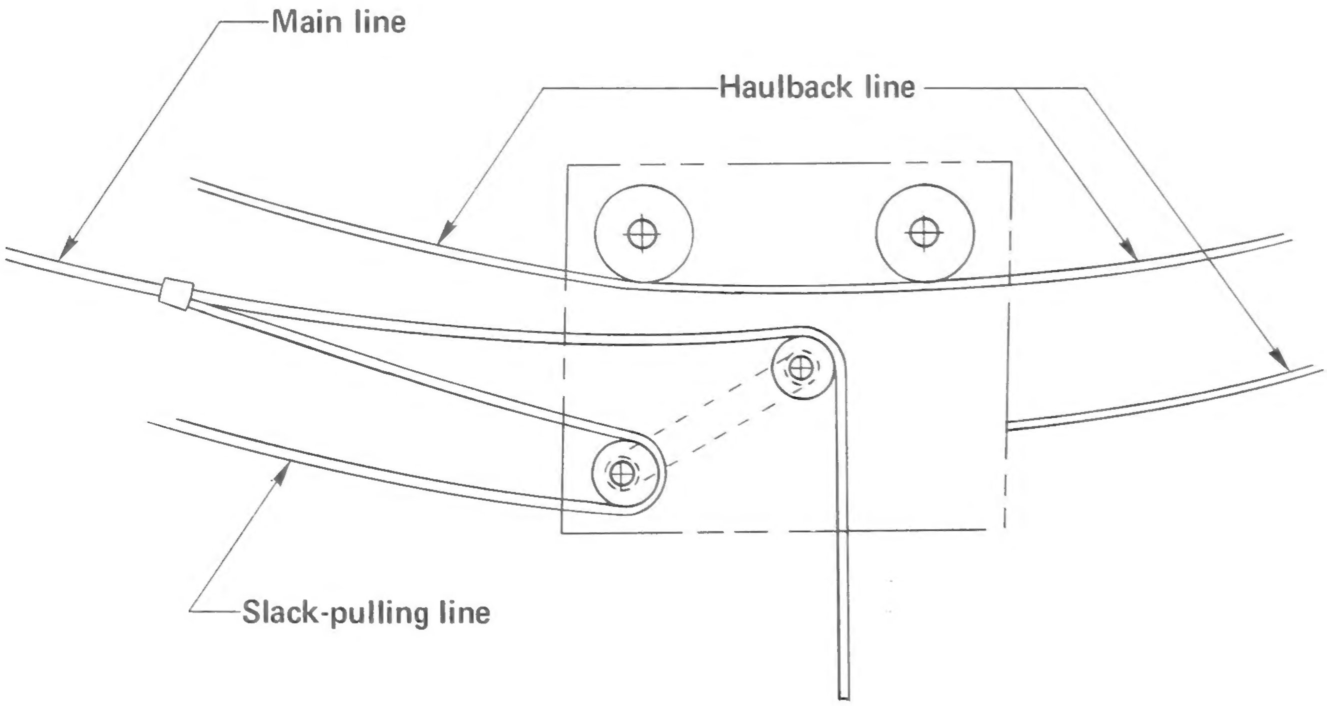


Figure 2(1).--Running skyline slack-pulling carriage.

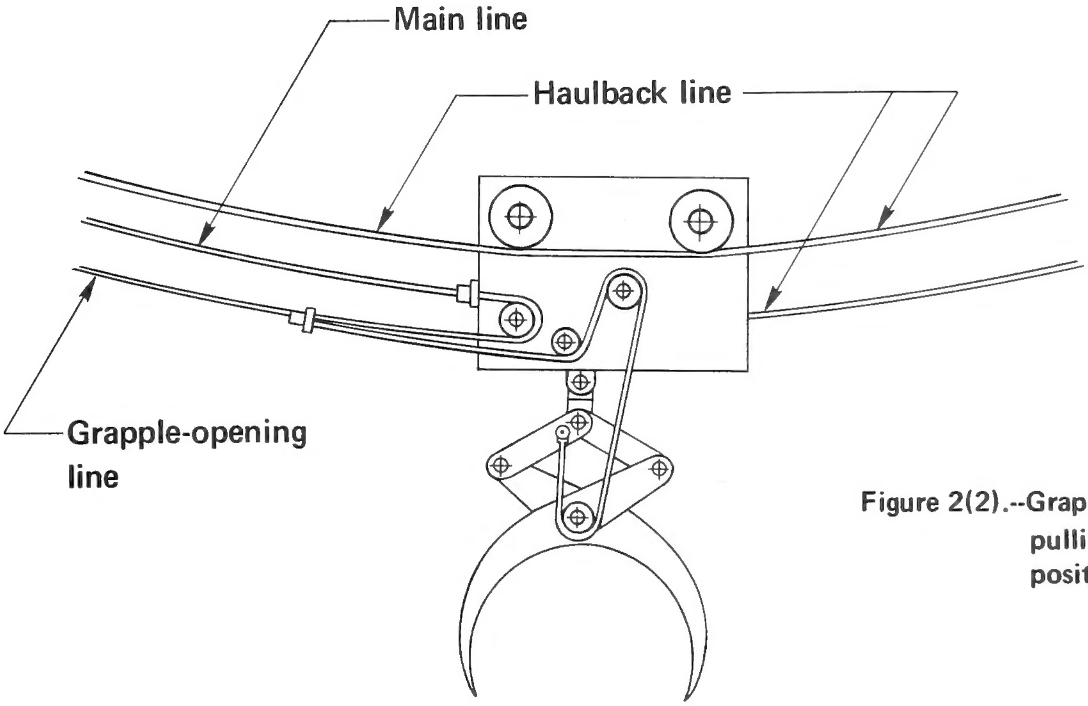


Figure 2(2).--Grapple attached to slack-pulling carriage (open position).

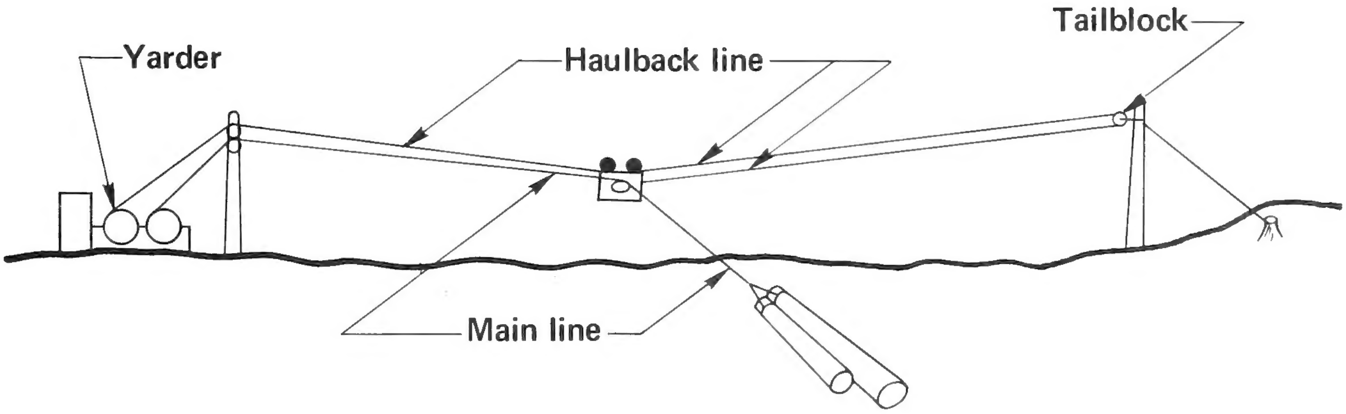


Figure 2(3).--Lines tensioned with log between tailblock and carriage.

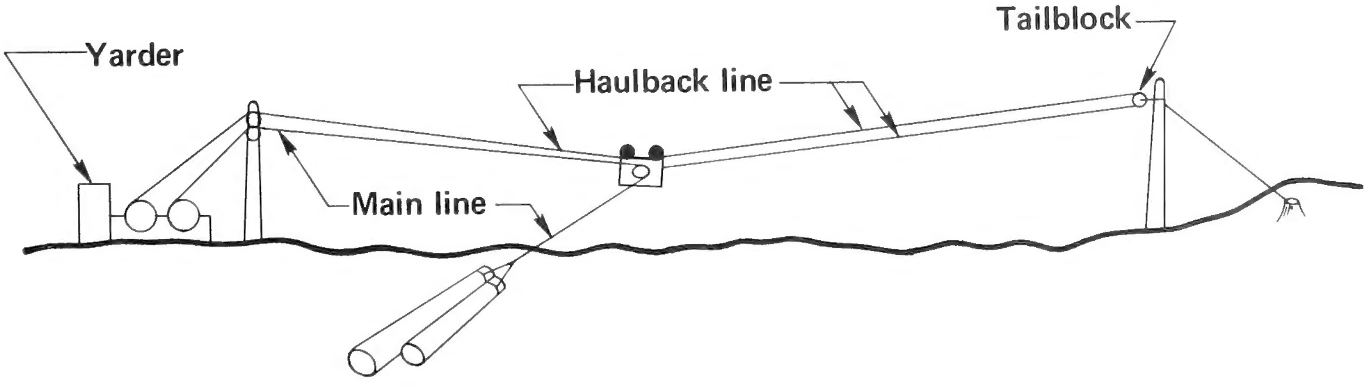


Figure 2(4).--Lines tensioned with log between yarder and carriage.

3.0 RUNNING SKYLINE ANALYSIS

This analysis is based on use of coefficients in the "Skyline Tension and Deflection Handbook"[2] for standing skylines. The approach used here is the same as that in the handbook. System capability is based on analysis of the running skyline in a static condition with the load at midspan. Tension in the lines is separated into tension due to the load and tension due to cable weight.

$$T = T_C + T_L$$

where: T is the total tension, T_C is the tension due to cable weight, and T_L is the tension due to load.

The tension due to cable weight is a function of unit cable weight, span length, and deflection, and can be found by use of methods described in the handbook. Therefore, this portion of the analysis is concerned only with the tension due to load. The problem here is to determine how the load is supported by the lines and how coefficients in the handbook can be related to the running skyline system. The following coefficients are tabulated in the handbook:

a. Coefficient (A)--tension due to cable weight – kips/station/pound of cable weight/foot – figure 11 or table 2

b. Coefficient (B)--tension due to load, carriage not clamped to skyline – kips/kip – figure 12 or table 3

c. Coefficient (C)--tension due to load, carriage clamped to skyline – kips/kip – figure 13 or table 4

[2] Lysons, Hilton H., and Mann, Charles N. Skyline tension and deflection handbook. Pacific Northwest Forest & Range Exp. Sta. U.S.D.A. Forest Serv. Res. Pap. PNW-39, 41 pp., illus. 1967.

The problem of determining tensions in the lines due to load can be solved by analysis of the system with weightless lines. Figure 3(1) shows a free body diagram of the running skyline carriage with weightless lines. This diagram represents both the single main line systems and those employing a main line plus a line for pulling slack or opening grapples. Since only the main line supports the load, the slack-pulling or opening line is ignored in the analysis.

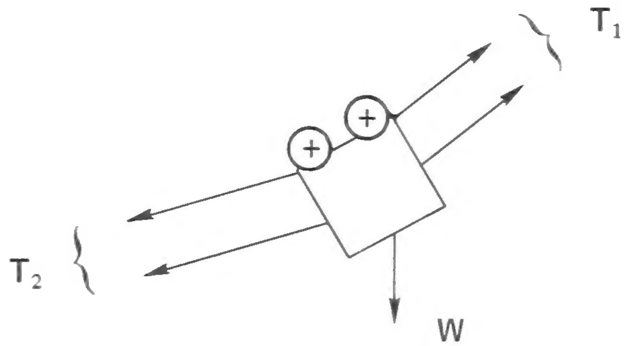


Figure 3(1).--Free body diagram of running skyline carriage. T_1 and T_2 are tension in the upper lines and tension in the lower lines due to load, and W is the weight of the carriage and the logs.

Figure 3(2) shows a force diagram of the weightless line system with the tensions combined into single vectors. This force diagram is also that

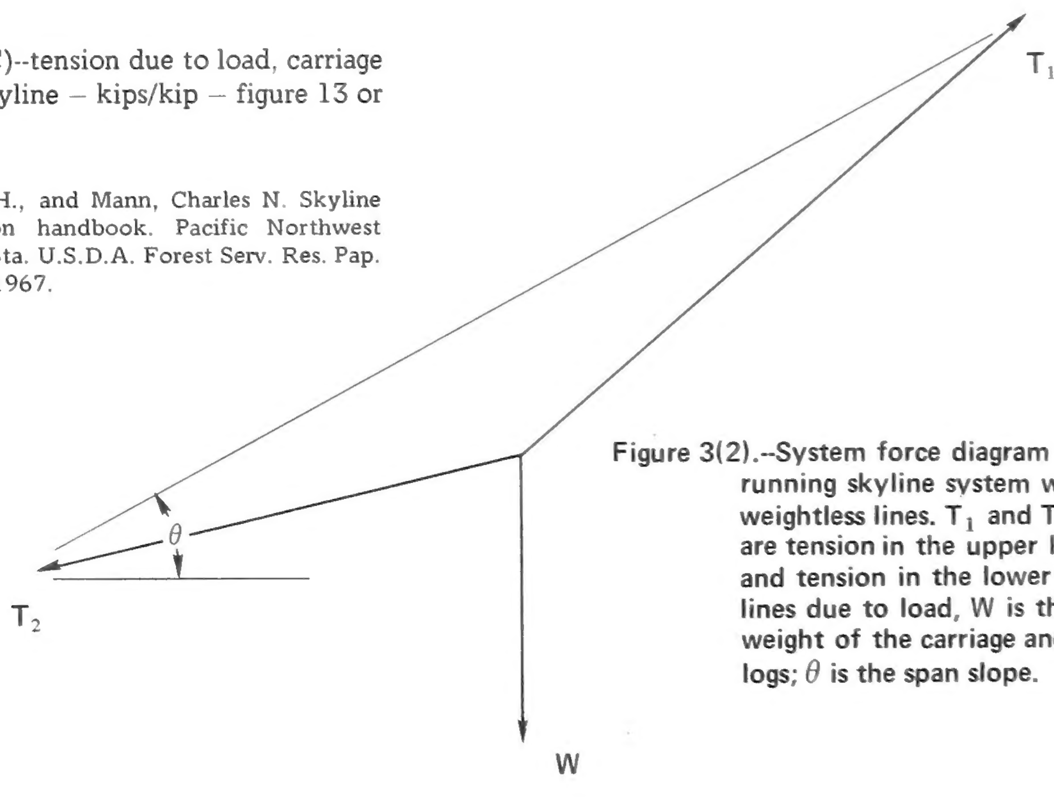


Figure 3(2).--System force diagram for running skyline system with weightless lines. T_1 and T_2 are tension in the upper lines and tension in the lower lines due to load, W is the weight of the carriage and logs; θ is the span slope.

of a single weightless line system with the carriage clamped to the skyline. Therefore, the tension in the upper lines due to load is the same as that with a clamped carriage. That is,

$$T_1 = W(C)$$

Now consider the force diagram of a weightless line system with the same load and a carriage which does not clamp to the skyline. This is shown in figure 3(3). In this case, the skyline supports only the component of load normal to the chord of the skyline, which is the vector component W cos θ. The snubbing force, W sin θ, is provided by an auxiliary line. Tension in the upper line is reduced vectorially by W sin θ, and tensions in the upper line and the lower line due to load are equal to T_2. Therefore, the tension in the lower lines due to load in the running skyline is the same as that in a system with a nonclamping carriage. That is,

$$T_2 = W(B)$$

It is necessary now to determine how these values of tension due to load are supported by the lines of the running skyline. Loading of the lines depends on whether the yarder is at the lower or the upper end, and these conditions must be treated separately.

3.1 SYSTEM WITH YARDER AT UPPER END

This configuration is shown in figure 3(4). H_1, H_2, and H_3 are the tensions in the haulback line due to load; M is the tension in the main line due to load; and W is the weight of the carriage and the logs.

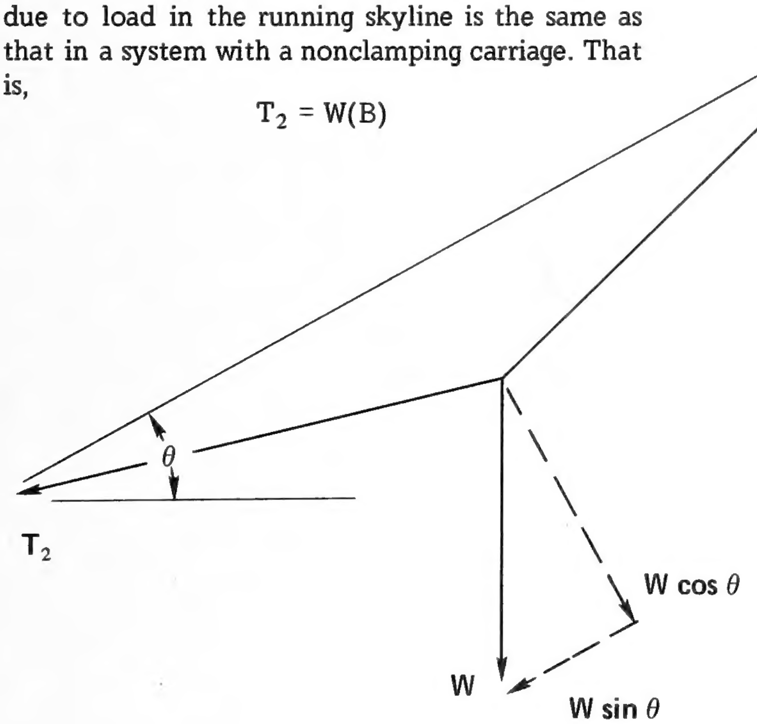


Figure 3(3).--System force diagram for weightless line skyline system with nonclamping carriage. T_2 is the tension in the skyline, W is the weight of the carriage and logs, and θ is the span slope. W cos θ is the component of load supported by the skyline and W sin θ is the component of load supported by a snubbing line.

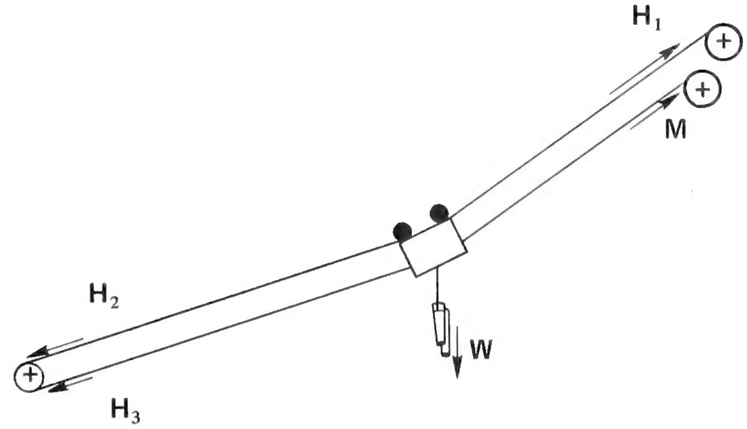


Figure 3(4).--Weightless line running skyline system with yarder at upper end. H_1, H_2, and H_3 are the tensions due to load in the haulback line segments, M is the tension due to load in the mainline, and W is the weight of the carriage and logs.

Tension due to load in the haulback is equal in the three segments,

$$H_1 = H_2 = H_3,$$

and,

$$T_2 = H_2 + H_3 = W(B)$$

The tension in the haulback due to load then is,

$$H_1 = \frac{W}{2}(B)$$

For the upper lines,

$$T_1 = H_1 + M,$$

$$CW = \frac{W}{2}(B) + M$$

Tension in the main line due to load, therefore, is,

$$M = \frac{W}{2}(2C\text{-}B).$$

3.2 SYSTEMS WITH YARDER AT LOWER END

This arrangement is shown in figure 3(5).

Again, tension in the three segments of the haulback is equal,

$$H_1 = H_2 = H_3,$$

and,

$$T_1 = H_2 + H_3 = W(C)$$

Tension in the haulback due to load then is,

$$H_2 = \frac{W}{2}(C)$$

Considering the lower lines,

$$T_2 = H_1 + M,$$

$$BW = \frac{W}{2}(C) + M$$

Tension in the main line due to load, therefore, is

$$M = \frac{W}{2}(2B\text{-}C)$$

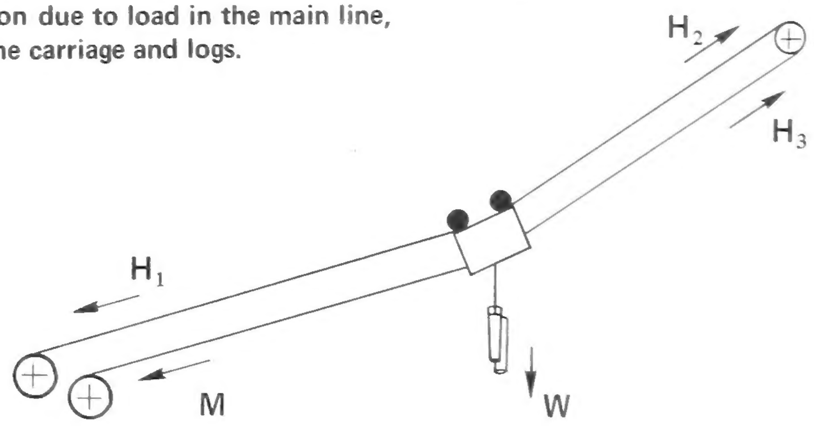
This analysis can now be applied to find the capability of the systems.

4.0 CAPABILITY

The system payload capability of running skylines can be determined from the graphical techniques and coefficients in the skyline handbook (see footnote 2) and the worksheets included in this research paper. The handbook may be obtained from Director, Pacific Northwest Forest and Range Experiment Station, P. O. Box 3141, Portland, Oregon 97208. The worksheets included in this research paper replace those in the footnote 1 reference.

The load path of the standing skyline is used for the running skyline analysis. This is a conservative approximation, but it is the only practical method available short of a computer analysis for each condition. The analysis on the worksheets is based on finding the capabilities of the main line and the haulback line separately. The smaller of the two payload capabilities is the capability of the system. This means that one of the lines must be operated at less than its allowable tension.

Figure 3(5).--Weightless line running skyline system with yarder at lower end. H_1, H_2, and H_3 are the tensions due to load in the haulback line segments, M is the tension due to load in the main line, and W is the weight of the carriage and logs.



The handbook analysis of single-span standing skylines results in payload capability based on the maximum safe working cable tension at the upper end of the span. When the handbook coefficients are applied to the running skyline system, a correct solution results for the case of the yarder at the upper end since both lines terminate at the upper end of the span. However, for the case of the yarder at the lower end, the main line does not extend to the upper end, and results based on this line are conservative since the reduction in tension due to elevation is neglected.

System payload capability is the maximum allowable vertical force that can be applied to the carriage. This corresponds to the weight of logs which can be carried free of the ground. Payload capability, when one end of the load is allowed to drag on the ground, depends on the slope, coefficient of friction, and log weight. Analysis of the condition with one end of the load allowed to drag is beyond the scope of this paper. If the main line is reeved through the carriage, the payload capability cannot exceed the main line safe working load.

Use of the worksheets for each yarder position is discussed below.

4.1 SYSTEM WITH YARDER AT UPPER END--Fig. 4(1)

In this case, the main line provides the snubbing force. If the lines are the same size, analysis of the main line capability will give the system capability. Detailed steps are listed below:

a. Make a plot of the skyline profile by following the procedures given in the "Skyline Tension and Deflection Handbook" and determine the allowable loaded deflection, the horizontal span length, and the slope of the span.

b. Obtain the required coefficients from the handbook, enter the carriage weight, and calculate the capability based on the main line. If the haulback line is the same size as the main line, the capability based on the main line is the system capability.

c. For systems with lines of different sizes, continue on the worksheet and determine the haulback line capability. System payload capability is the lower of the two capabilities.

4.2 SYSTEM WITH YARDER AT LOWER END-- Fig. 4(2)

For this configuration, the haulback line provides the snubbing force, and system capability is based on this line if both lines are the same size. Steps on the worksheet are the same as those for the yarder at the upper end except the haulback line analysis is performed first.

4.3 RUNNING SKYLINE EXAMPLES

A profile plot of a proposed skyline road yields the following information:

Horizontal span length	800 feet
Slope of span	40 percent
Allowable loaded deflection	10 percent

It is assumed that there is suitable access at the upper and lower ends of the skyline road, and that the yarder is equipped with 3/4-inch-diameter, extra-improved, plow steel main and haulback lines.

Figures 4.3(1) and 4.3(2) show examples of the applications of the sample worksheets (figs. 4(1) and 4(2)) in calculating the system's payload capabilities for either uphill or downhill yarding under the conditions given. Note that where the main and haulback lines are the same diameter, it is not necessary to calculate the capabilities of both lines to determine the system's capabilities.

Unit No.________
Skyline Road No.________

DETERMINE FROM SKYLINE PROFILE

Allowable loaded deflection ________ percent
Horizontal span length (one station = 100 feet) ________ stations
Slope of span ________ percent

OBTAIN COEFFICIENTS FROM "SKYLINE TENSION AND DEFLECTION HANDBOOK"

Coefficient A (fig. 11 or table 2) kip/sta./lb./ft. ________
Coefficient B (fig. 12 or table 3) ________ kip/kip
Coefficient C (fig. 13 or table 4) ________ kip/kip
Coefficient D (2 x coeff. C ________ - coeff. B ________) ________ kip/kip

CARRIAGE WEIGHT (1 kip = 1,000 pounds) ________ kips

MAIN LINE ANALYSIS:

Specifications: Diameter ________ inches, Weight ________ pounds/foot
Breaking strength ________ kips, Factor of safety ________
Safe working load ________ kips (or maximum yarder line pull)

MAIN LINE CAPABILITY:

Safe working load ________ kips
Subtract (coeff. A ________ x ________ stations x ________ pounds/foot) - ________ kips
Remaining payload capability (R.P.C.) ________ kips
Main line gross capability = $\frac{\text{R.P.C. \_\_\_\_\_\_\_\_ kips x 2}}{\text{Coeff. D \_\_\_\_\_\_\_\_}}$ = ________ kips
Subtract carriage weight - ________ kips
Main line payload capability ________ kips
If main and haulback are the same size, this is system capability)

HAULBACK LINE ANALYSIS:

Specifications: Diameter ________ inches, Weight ________ pounds/foot
Breaking strength ________ kips, Factor of safety ________
Safe working load ________ kips (or maximum yarder line pull)

HAULBACK LINE CAPABILITY:

Safe working load ________ kips
Subtract (coeff. A ________ x ________ stations x ________ pounds/foot) - ________ kips
Remaining payload capability (R.P.C.) ________ kips
Haulback line gross capability = $\frac{\text{R.P.C. \_\_\_\_\_\_\_\_ kips x 2}}{\text{Coeff. B \_\_\_\_\_\_\_\_}}$ = ________ kips
Subtract carriage weight - ________ kips
Haulback payload capability ________ kips

SYSTEM PAYLOAD CAPABILITY*

*System payload is the lower of the main line or the haulback capability.

Figure 4(1).--Running skyline worksheet (yarder at upper end).

Unit No.________
Skyline Road No.________

DETERMINE FROM SKYLINE PROFILE

Allowable loaded deflection ________ percent
Horizontal span length (one station = 100 feet) ________ stations
Slope of span ________ percent

OBTAIN COEFFICIENTS FROM "SKYLINE TENSION AND DEFLECTION HANDBOOK"

Coefficient A (fig. 11 or table 2) kip/sta./lb./ft. ________
Coefficient B (fig. 12 or table 3) ________ kip/kip
Coefficient C (fig. 13 or table 4) ________ kip/kip
Coefficient D (2 x coeff. B ________ - coeff. C ________) ________ kip/kip

CARRIAGE WEIGHT (1 kip = 1,000 pounds) ________ kips

HAULBACK LINE ANALYSIS:

Specifications: Diameter ________ inches, Weight ________ pounds/foot
Breaking strength ________ kips, Factor of safety ________
Safe working load ________ kips (or maximum yarder line pull)

HAULBACK LINE CAPABILITY:

Safe working load ________ kips
Subtract (coeff. A ________ x ________ stations x ________ pounds/foot) - ________ kips
Remaining payload capability R.P.C.) ________ kips
Haulback gross capability = $\frac{\text{R.P.C. \_\_\_\_\_\_\_\_ kips x 2}}{\text{Coeff. C \_\_\_\_\_\_\_\_}}$ ________ kips
Subtract carriage weight - ________ kips
Haulback line payload capability ________ kips
(If main and haulback are the same size, this is system capability)

MAIN LINE ANALYSIS:

Specifications: Diameter ________ inches, Weight ________ pounds/foot
Breaking strength ________ kips, Factor of safety ________
Safe working load ________ kips (or maximum yarder line pull)

MAIN LINE CAPABILITY:

Safe working load ________ kips
Subtract (coeff. A ________ x ________ stations x ________ pounds/foot) - ________ kips
Remaining payload capability (R.P.C.) ________ kips
Main line gross capability = $\frac{\text{R.P.C. \_\_\_\_\_\_\_\_ kips x 2}}{\text{Coeff. D \_\_\_\_\_\_\_\_}}$ ________ kips
Subtract carriage weight - ________ kips
Main line payload capability ________ kips

SYSTEM PAYLOAD CAPABILITY* ________ kips

*System payload is the lower of the main line or the haulback capability.

Figure 4(2).--Running skyline worksheet (yarder at lower end).

Unit No.____________
Skyline Road No.________

DETERMINE FROM SKYLINE PROFILE

Allowable loaded deflection — 10 percent
Horizontal span length (one station = 100 feet) — 8 stations
Slope of span — 40 percent

OBTAIN COEFFICIENTS FROM "SKYLINE TENSION AND DEFLECTION HANDBOOK"

Coefficient A (fig. 11 or table 2) kip/sta./lb./ft. — 0.176
Coefficient B (fig. 12 or table 3) — 2.54 kip/kip
Coefficient C (fig. 13 or table 4) — 2.91 kip/kip
Coefficient D (2 x coeff. C 2.91 - coeff. B 2.54) — 3.28 kip/kip

CARRIAGE WEIGHT (1 kip = 1,000 pounds) — 0.5 kips

MAIN LINE ANALYSIS:

Specifications: Diameter 3/4 inches, Weight 1.04 pounds/foot
Breaking strength 58.8 kips, Factor of safety 3
Safe working load 19.6 kips (or maximum yarder line pull)

MAIN LINE CAPABILITY:

Safe working load — 19.60 kips
Subtract (coeff. A 0.176 x 8 stations x 1.04 pounds/foot) — - 1.46 kips
Remaining payload capability (R.P.C.) — 18.14 kips
Main line gross capability = $\frac{\text{R.P.C. } 18.14 \text{ kips x 2}}{\text{Coeff. D } 3.28}$ — 11.06 kips
Subtract carriage weight — - 0.5 kips
Main line payload capability — 10.56 kips
(If main and haulback are the same size, this is system capability)

HAULBACK LINE ANALYSIS:

Specifications: Diameter 3/4 inches, Weight 1.04 pounds/foot
Breaking strength 58.8 kips, Factor of safety 3
Safe working load 19.6 kips (or maximum yarder line pull)

HAULBACK LINE CAPABILITY:

Safe working load — 19.60 kips
Subtract (coeff. A 0.176 x 8 stations x 1.04 pounds/foot) — - 1.46 kips
Remaining payload capability (R.P.C.) — 18.14 kips
Haulback line gross capability = $\frac{\text{R.P.C. } 18.14 \text{ kips x 2}}{\text{Coeff. B } 2.54}$ — 14.28 kips
Subtract carriage weight — - 0.5 kips
Haulback payload capability — 13.78 kips

SYSTEM PAYLOAD CAPABILITY* — 10.56 kips

*System payload is the lower of the main line or the haulback capability.

Figure 4.3(1).--Running skyline worksheet (yarder at upper end).

Unit No.______________
Skyline Road No.________

DETERMINE FROM SKYLINE PROFILE

Allowable loaded deflection — 10 percent
Horizontal span length (one station = 100 feet) — 8 stations
Slope of span — 40 percent

OBTAIN COEFFICIENTS FROM "SKYLINE TENSION AND DEFLECTION HANDBOOK"

Coefficient A (fig. 11 or table 2) kip/sta./lb./ft. — 0.176
Coefficient B (fig. 12 or table 3) — 2.54 kip/kip
Coefficient C (fig. 13 or table 4) — 2.91 kip/kip
Coefficient D (2 x coeff. B 2.54 - coeff. C 2.91) — 2.17 kip/kip

CARRIAGE WEIGHT (1 kip = 1,000 pounds) — 0.5 kips

HAULBACK LINE ANALYSIS:

Specifications: Diameter 3/4 inches, Weight 1.04 pounds/foot
Breaking strength 58.8 kips, Factor of safety 3
Safe working load 19.6 kips (or maximum yarder line pull)

HAULBACK LINE CAPABILITY:

Safe working load — 19.60 kips
Subtract (coeff. A 0.176 x 8 stations x 1.04 pounds/foot) — - 1.46 kips
Remaining payload capability (R.P.C.) — 18.14 kips
Haulback gross capability = R.P.C. 18.14 kips x 2 / Coeff. C 2.91 — 12.47 kips
Subtract carriage weight — - 0.50 kips
Haulback line payload capability — 11.97 kips
(If main and haulback are the same size, this is system capability)

MAIN LINE ANALYSIS:

Specifications: Diameter 3/4 inches, Weight 1.04 pounds/foot
Breaking strength 58.8 kips, Factor of safety 3
Safe working load 19.6 kips (or maximum yarder line pull)

MAIN LINE CAPABILITY:

Safe working load — 19.60 kips
Subtract (coeff. A 0.176 x 8 stations x 1.04 pounds/foot) — - 1.46 kips
Remaining payload capability (R.P.C.) — 18.14 kips
Main line gross capability = R.P.C. 18.14 kips x 2 / Coeff. D 2.17 — 16.72 kips
Subtract carriage weight — - 0.50 kips
Main line payload capability — 16.22 kips

SYSTEM PAYLOAD CAPABILITY* — 11.97 kips

*System payload is the lower of the main line or the haulback capability.

Figure 4.3(2).--Running skyline worksheet (yarder at lower end).

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1969. Mechanics of running skylines. U.S.D.A. Forest Serv. Res. Pap. PNW-75, 11 pp., illus. Pacific Northwest Forest & Range Experiment Station, Portland, Oregon.

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Headquarters for the PACIFIC NORTHWEST FOREST AND RANGE EXPERIMENT STATION is in Portland, Oregon. The Station's mission is to provide the scientific knowledge, technology, and alternatives for management, use, and protection of forest, range, and related environments for present and future generations. The area of research encompasses Alaska, Washington, and Oregon, with some projects including California, Hawaii, the Western States, or the Nation. Project headquarters are at:

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